34-year record of proxy-Shortwave cloud albedo from SBUV observations compared with historical/AMIP CESM2 model runs

Clark Weaver[1,2] Dong Wu[3] Gordon Labow[1,4] David Haffner[1,4] Pawan Bhartia[1]
Ross Salawitch[2] Lauren Borgia[2] Laura McBride[2]

1 Atmospheric Chemistry and Dynamics Branch, NASA Goddard Space Flight Center
2 Earth System Science Interdisciplinary Center (ESSIC), U. Maryland.
3 Climate and Radiation Laboratory, NASA Goddard Space flight Center
4 Science Systems and Applications (SSAI), Inc.,

A41M-2844 Board: 2000
Thursday, 15 December 2022
02:45 - 6:15pm
A45L - Climate Sensitivity and Feedbacks: Advances and New Paradigms II

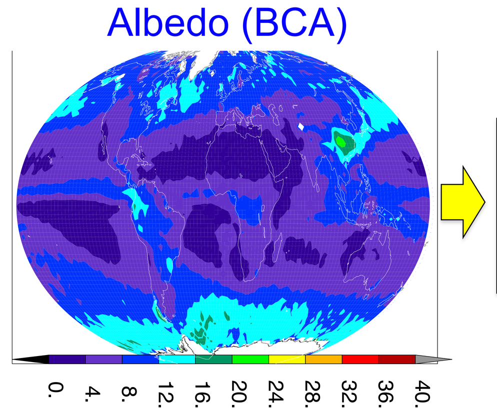
Introduction

Quantifying global cloudiness is critical to understanding Earth's radiation budget and validating climate model feedbacks. We present a 34-year record of Shortwave cloud and aerosol albedo from the NOAA /NASA SBUV (340nm) sensing satellite instruments: Nimbus-7, NOAA-9, 11, 14, 16, 17, 18 & 19.

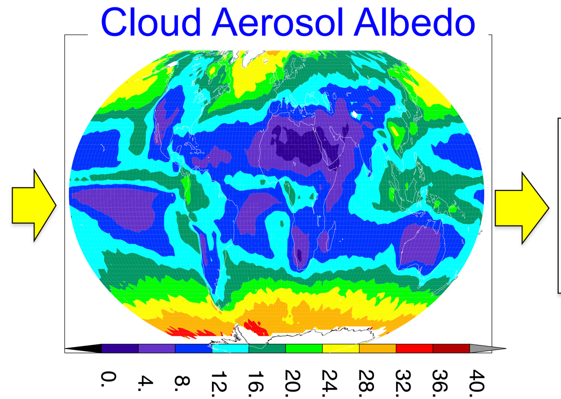
We produce diurnally adjusted Black-sky Cloud Albedo (BCA) from the Level-2 measured narrow band intensities. Then we estimate the broadband albedo using a multiple non-linear regression approach along with several years of CERES cloud albedo for training. Finally, we compare our proxy SW albedo with CMIP6 models.

SBUV level-2 **340nm Intensities** → Calibration over Ice Sheets → **Cloud Aerosol Optical Depth** → **Empirically Adjust Optical Depth to 1:30pm** → Black-sky Cloud Aerosol Albedo (BCA) → Train with CERES using multivariate approach to produce… → Proxy Short Wave Cloud Aerosol Albedo → Compare with CMIP6 Cloud Aerosol Albedo

Black-sky Cloud Aerosol Albedo (BCA)

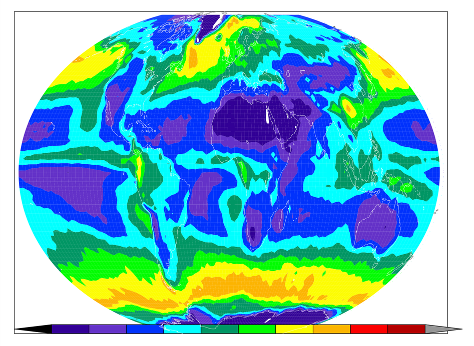


Proxy Short Wave Cloud Aerosol Albedo

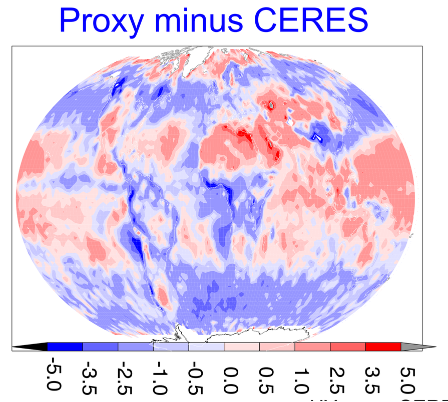


Compare with CERES

CERES Cloud Aerosol Albedo

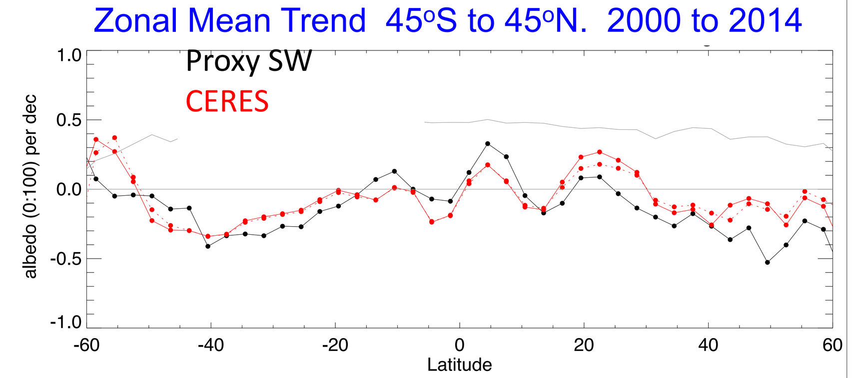


Proxy minus CERES



At any spatial location, mean difference is on average < 3.5% albedo

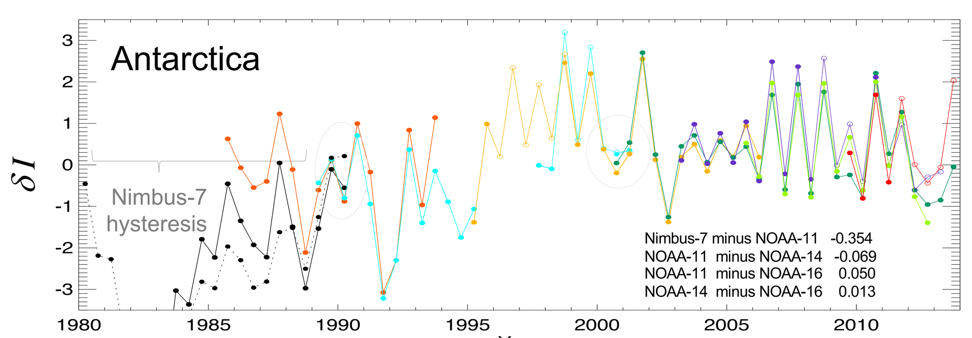
Zonal Mean Trend 45°S to 45°N. 2000 to 2014

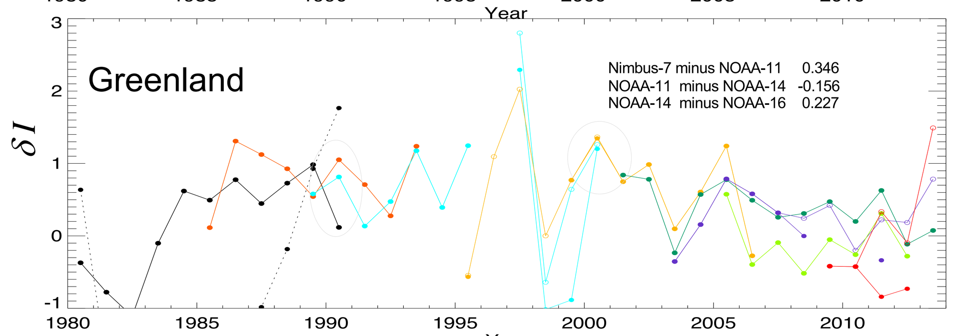


Good agreement between proxy and CERES SW cloud albedo zonal mean trends

Calibration over icesheets…

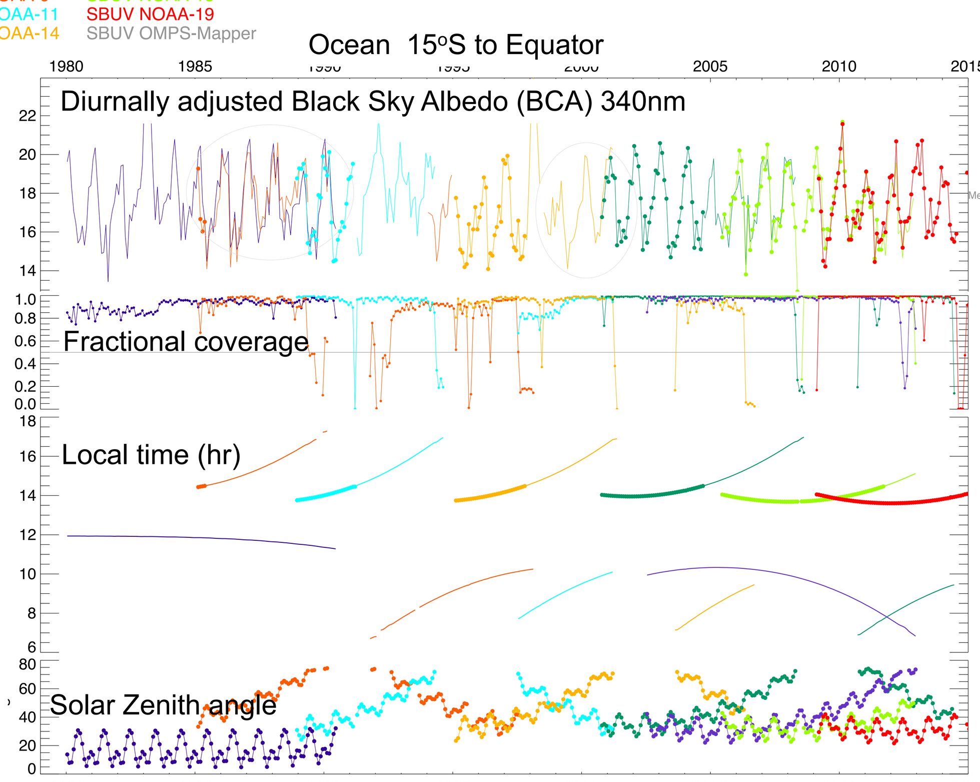
by adjusting SBUV gain so overlapping satellites match





δI = solar zenith angle normalized intensity anomaly

check over tropics to see if agreement holds.



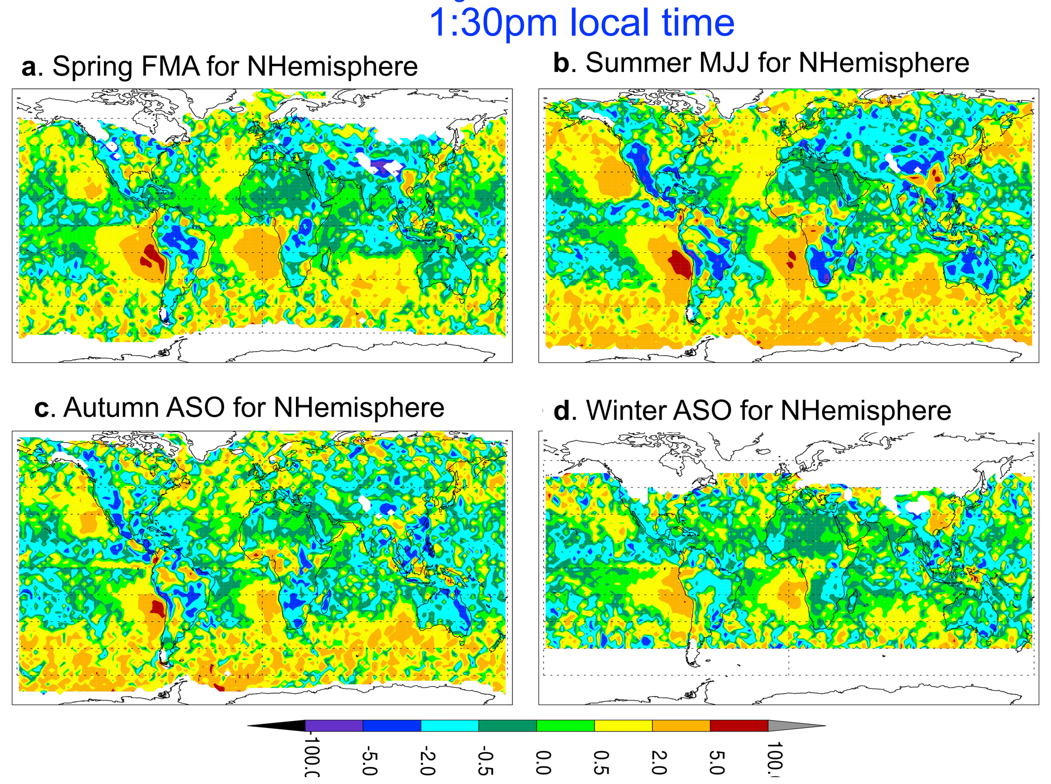
Nimbus-7, NOAA-9 and NOAA-11 have nice over-lapping BCA agreement.

NOAA-14 and NOAA-16 also match.

Fractional coverage for each 15° latitude band is consistently above 80% throughout record.

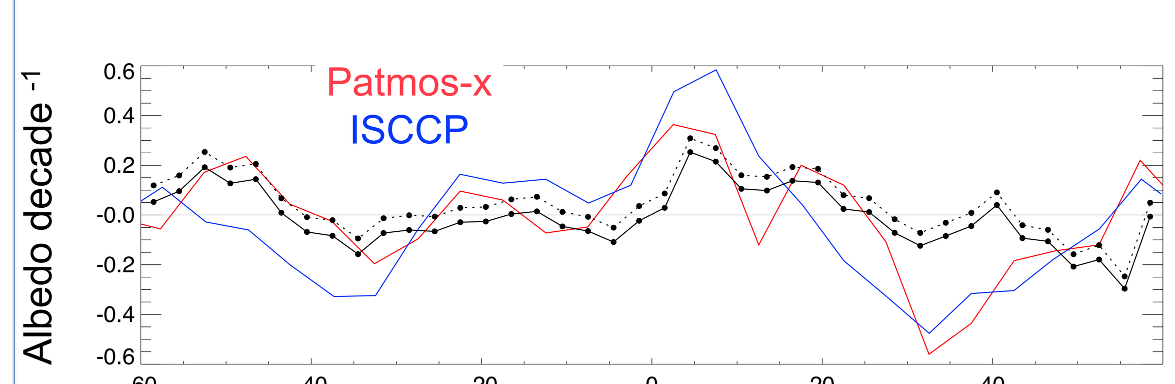
BCA values have been diurnally adjusted to 1:30pm local time. Many SBUV sensors have observations within 1 hour of this time. They are given added weight when determining trends.

Diurnal cycle ($COD_{morning} - COD_{afternoon}$) used to adjust COD to 1:30pm local time



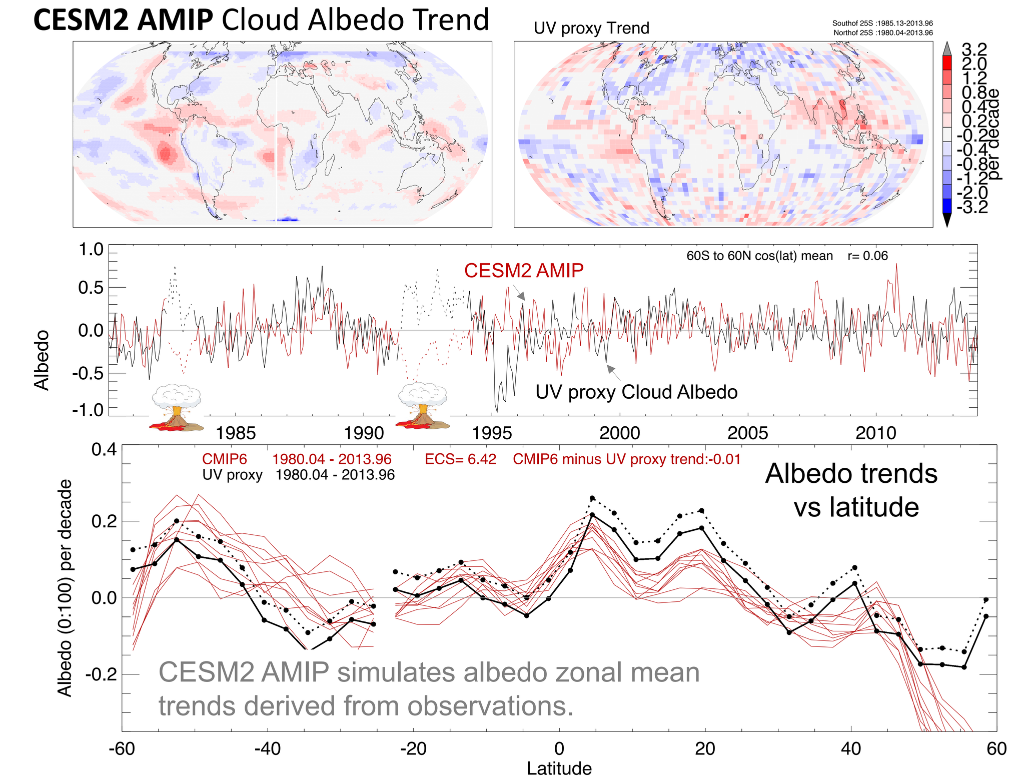
Climatology of diurnal cycle using all NOAA SBUV instruments. Marine stratocumulus show early morning clouds, especially in summer. Over land cycle is strongest in summer with higher COD values in afternoon.

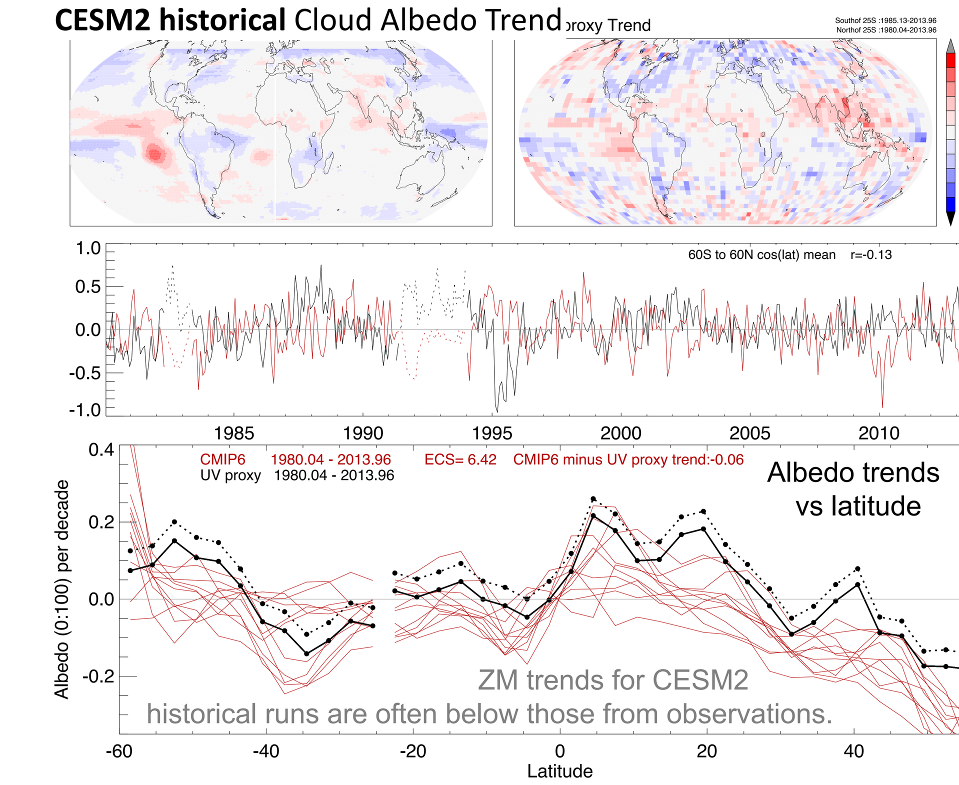
Compare our SW proxy trends with ISCCP and Patmos-X SW cloud albedo trends



Good agreement with Patmos-X south of 20° N

Comparison of SW cloud (only) albedo from CESM2 with our proxy SW cloud+aerosol albedo





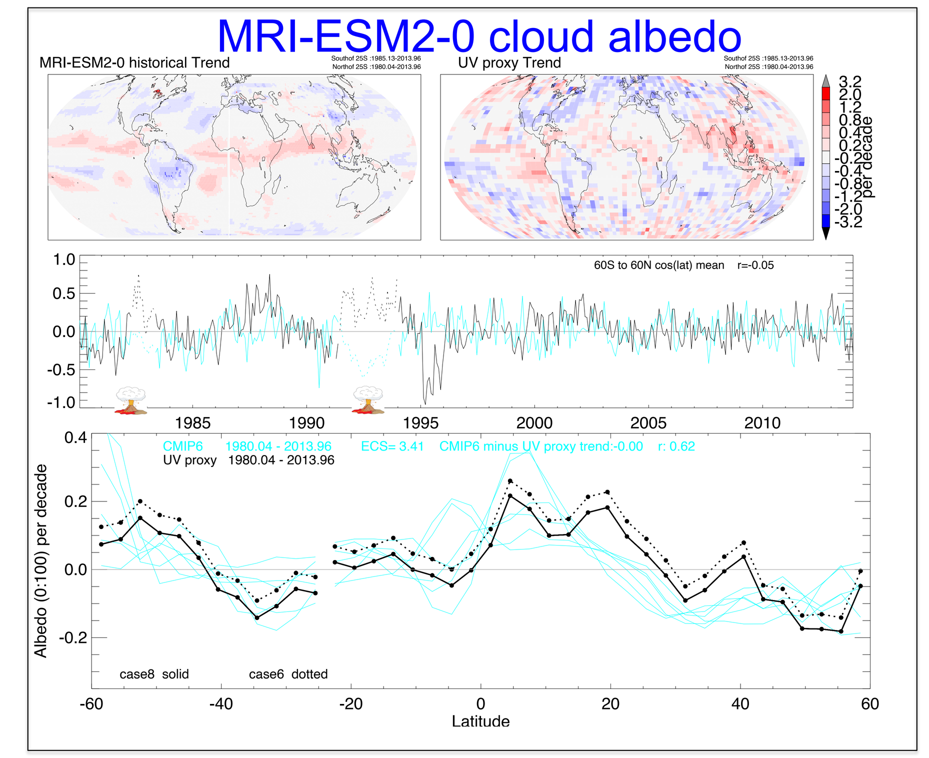
CESM2 SW cloud albedo = (rsut – rsutcs) / rsdt

rsut : TOA outgoing SW flux all sky
rsutcs: TOA outgoing SW flux assuming clear sky with aerosols
rsdt: incoming SW flux

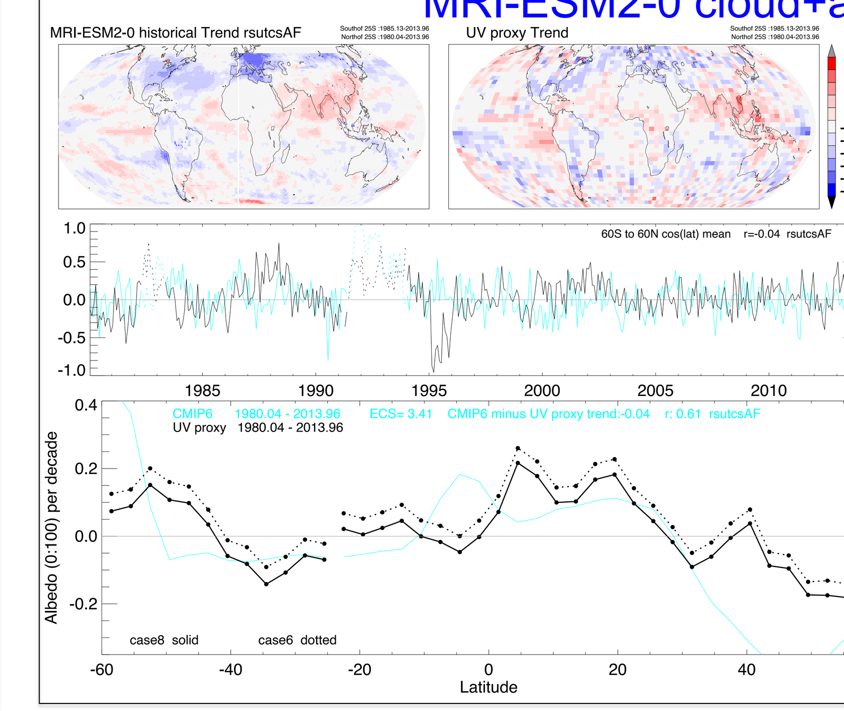
Our SW albedo proxy has a positive volcanic response since it includes aerosols.

CESM2 is cloud only and has different response (negative)

MRI-ESM2-0 cloud albedo



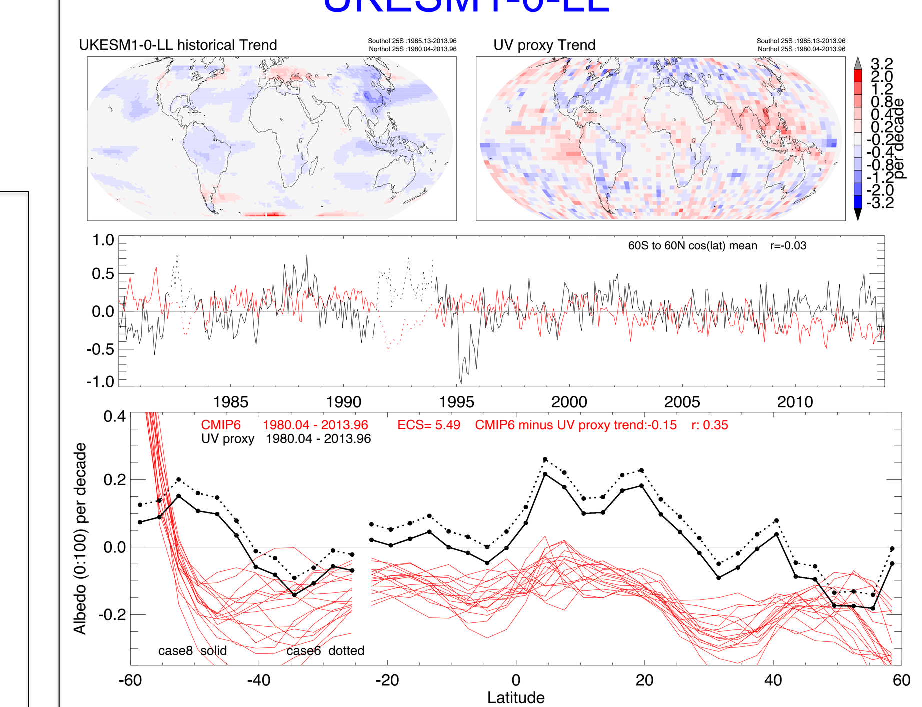
MRI-ESM2-0 cloud+aerosol albedo



Offers direct comparison to our observations.

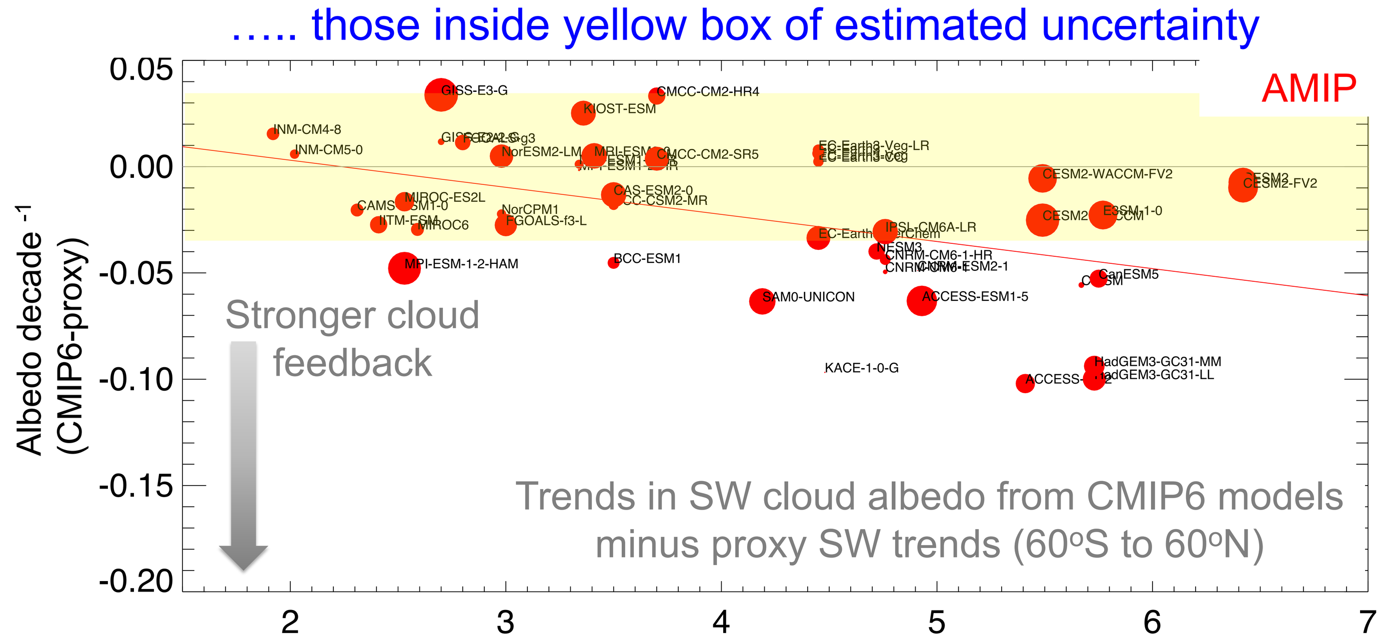
Positive volcanic response similar to observations.

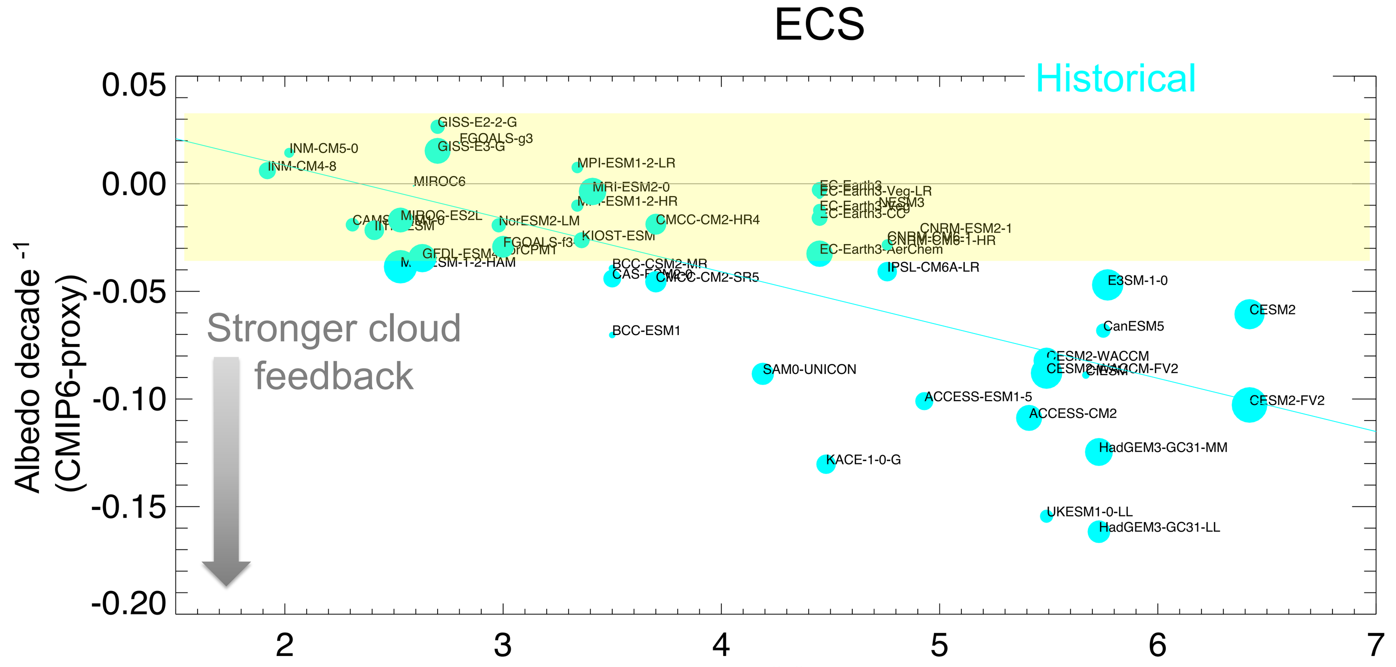
UKESM1-0-LL



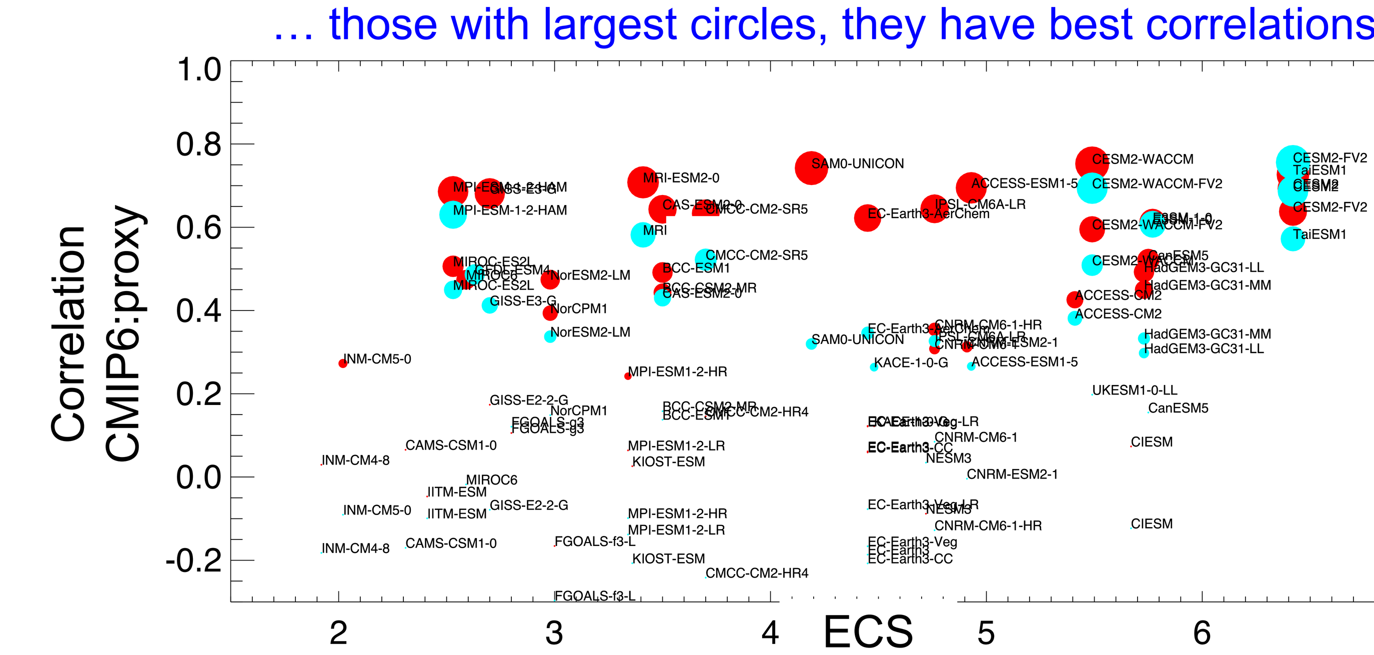
UKESM1-0-LL CMIP6 model has significantly more cloud dissipation compared with observations. This suggests model SW cloud feedback is too strong.

Which models agree with global mean SW proxy cloud albedo trend? ….. those inside yellow box of estimated uncertainty





Which models match latitudinal variability in proxy SW trend? … those with largest circles, they have best correlations



1 Compared with historical simulations, the AMIP runs better capture 1) the latitudinal variability of observed zonal mean trends and 2) the observed global mean trends. Observational comparison with AMIP runs are less demanding because AMIP simulations are atmosphere-only runs using prescribed sea surface temperature (SST) and sea ice concentrations from 1979 to present. On the other hand, the historical simulations use a coupled Atmosphere-Ocean GCM. Successful historical comparisons with observations mean that the GCM must simulate an accurate SST distribution, as the climate warms, in addition to simulating the connection between SST and cloudiness.

2 Our historical comparison result (left) is consistent with previous studies that conclude that model simulated cloud feedback explains much of the spread in Equilibrium Climate Sensitivity (ECS) [1,2,3]. Models with ECS > 5 have global cloudiness trends that are below our observations suggesting that their simulated cloud feedbacks are too strong.

!!! CMIP6 modelers: Please archive TOA outgoing flux clear sky *aerosol free* (rsutcsaf) !!

1 Cess, R. D. (1990). Intercomparison and interpretation of cloud-climate feedback processes in nineteen atmospheric general circulation models. JGR, 95, 16,601–16,615.
2 Bony, S., and J.-L. Dufresne (2005), Marine boundary layer clouds at heart of tropical cloud feed-back uncertainties in climate models, GRL. 32, L20806, doi:10.1029/2005GL02385
3 Zelinka, M. D., et al. (2020). Causes of higher climate sensitivity in CMIP6 models GRL, 47, e2019GL085782. https:// doi.org/10.1029/2019GL085782